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RESEARCH MEMORANDUM

AN INVESTIGATION OF LOADS ON AILERONS

AT TRANSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
May 27, 1955

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RESEARCH MEMORANDUM

AN INVESTIGATION OF LOADS ON AILERONS AT TRANSONIC SPEEDS

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SUMMARY

Some aileron load characteristics for three thin wings varying in sweep have been presented for Mach numbers from 0.80 to 1.05. For the transonic Mach number range, shock effects exert a large influence on the loading, but the exact location of each shock for a specific wing design cannot be catalogued at the present time. It is shown, however, that the aileron loading, although greater in magnitude than at subsonic speeds, nevertheless varies in as uniform a fashion as at subsonic speeds.

INTRODUCTION

Limited information obtained from unpublished data for investigations at the Langley Aeronautical Laboratory has indicated that loading on flap-type controls may change in a nonuniform fashion in the transonic range. The purpose of this paper is to present a few loading characteristics of typical wing-aileron configurations which have recently been obtained in the Langley 16-foot transonic tunnel.

SYMBOLS

A	aspect ratio
b	wing or aileron span
c	wing chord
$\bar{c}$	average aileron chord
C_N	aileron normal-force coefficient $\frac{N}{qS_a}$

[redacted]

[redacted]

c_r root chord

M Mach number

N normal force

P pressure coefficient

q dynamic pressure

S_a aileron area

x/c fraction of wing chord

$x/\bar{c}$ fraction of aileron average chord

y/b fraction of aileron span

α angle of attack

δ aileron deflection

Λ angle of sweepback

λ taper ratio

DESCRIPTION OF MODELS

The plan forms of the configurations tested are shown in figure 1. Three wing-body combinations having unbalanced ailerons were investigated: a 4-percent-thick unswept wing, a 4-percent-thick swept wing, and a 3-percent-thick triangular wing. The unswept wing had outboard ailerons extending over 40 percent of the wing semispan with a chord of 25 percent of the wing chord. The swept wing had centrally located ailerons also extending over 40 percent of the semispan with the aileron chord 30 percent of the wing chord. The triangular wing had an outboard aileron of 37 percent semispan extent with a constant chord of 10 percent of the wing root chord. Other characteristics of the configurations, including the location of the inboard end of each aileron, are noted in figure 1. Loads information on the ailerons of the unswept and swept wings was obtained from two-component strain-gage balances located inside the wings. Pressure-distribution measurements were, however, also obtained for the undeflected-aileron case for the entire chord at each of three spanwise stations on the unswept wing and six spanwise stations on the swept wing. The loading on the triangular-wing aileron was determined from pressure-distribution measurements at two spanwise stations over the aileron out of the six available stations over the wing.

DISCUSSION

Because shock formations occur at transonic speeds, it was reasonable to expect that the formation and movement of the shocks would introduce nonlinearities in control loads. The most predominant shocks for the three representative wings with undeflected controls are illustrated in figure 2 for what may be characterized as the Mach numbers for which the shocks would be expected to exert the greatest influence over the control area. The observations which follow would necessarily be modified somewhat for deflected flaps.

The flow-field shock is a normal shock and its rapid axial movement across and off the wing with increasing angle of attack at a given Mach number is responsible for a change in the pressure-distribution shape from triangular to generally rectangular which will be shown to cause some nonlinearities in loading characteristics. Examples of typical pressure-distribution changes are illustrated in figure 2.

At moderate and high angles of attack the wing leading-edge and trailing-edge shocks develop, but as they are relatively weak in the case of thin wings and are restricted in movement to portions of the wing, one would not expect them to cause severe loading changes. These latter shocks may, however, induce high fluctuating loads and further studies are being made of this aspect. Although there are similarities in the shock patterns in the transonic range between different wing designs, the exact location of each shock for a specific wing is unpredictable at the present time.

Typical effects of Mach number and deflection on the aileron loading characteristics of the three representative wings will now be discussed.

Several loading variations obtained on the aileron of the unswept wing are shown in figure 3. Aileron normal-force coefficient is plotted against angle of attack for three nominal control deflections, -10°, 0°, and 10°. The characteristics at a Mach number of 0.8 which is representative of the high subsonic speed variation are shown with the broken lines, and the variation at a Mach number of 0.94 which is typical of the transonic range is indicated by the solid line.

At a Mach number of 0.80 the aileron is ineffective in developing normal-force load with change in angle of attack up to angles of about 8° which represents the approximate maximum lift for the wing at this Mach number. Above 8° the loading over the control changes from triangular to trapezoidal in shape and the loading increases with angle of attack.

At a Mach number of 0.94 the aileron becomes effective in producing increased loading with angle-of-attack change at much lower angles and the increase in load is generally greater than at the lower Mach numbers.

The rate of increase in loading at low angles of attack contrasted with high angles of attack is directly related to the change in pressure distribution from triangular to rectangular (fig. 2) which in turn is influenced by the shock pattern. At transonic Mach numbers from 0.92 to 1.05, the values of aileron normal-force coefficient lie very close to those shown for 0.94 Mach number.

For the test speed range, which was from a Mach number of 0.70 to 1.05, the spread in magnitude of load carried at the positive and negative aileron deflections remains approximately constant with angle-of-attack change.

Figure 4 shows similar information obtained with the 45° swept-wing aileron. The nominal control deflections are now 15° and -15° instead of 10°. Again the Mach numbers illustrated are 0.8 and 0.94. Here again the data shown for a Mach number of 0.94 is typical of the results obtained at Mach numbers from 0.92 to 1.05.

There are several differences between this aileron and the unswept-wing aileron. In the first place, the effect of Mach number on the load carried by the aileron (compare the values of load coefficient at 12° angle of attack) is not as great as that on the unswept-wing aileron. Secondly, the spread in magnitude of load for positive and negative deflections does not remain constant with angle of attack for the swept wing. It may also be noted that the swept wing with 15° aileron deflection carried about the same unit load at the lower angles of attack as the unswept-wing aileron with 10° deflection (fig. 3).

The loading characteristics of the outboard aileron on the triangular wing are shown in figure 5. The aileron load variations with angle of attack at Mach numbers of 0.80 and 0.98 are presented for nominal control deflections of 0°, 15°, and -15°.

Several predominant characteristics of this control should be noted. The magnitude of the unit load carried by the triangular-wing aileron for the same control deflections is generally greater than that of the swept-wing aileron; the transonic variation in aileron loading with angle of attack is more uniform than at high subsonic speeds; the effect of Mach number on the load carried by the aileron is greater at zero and positive deflections than at negative control deflections.

Some variation of aileron center-of-load location with Mach number for the three ailerons tested is shown in figure 6. Chordwise center of load referenced to the average chord of the aileron $\bar{c}$ and spanwise center of load referenced to the span of the aileron b are plotted on the vertical scales with Mach number on the horizontal axis. The center-of-load locations for approximately comparable deflections for the three controls are illustrated in this figure. An attempt has been made to indicate typical

locations of center-of-load travel for constant angles of attack and varying control deflection, and constant control deflection with changing angle of attack. The center-of-load locations may, however, vary over greater limits than those shown in the case where the load or moments approach zero.

The chordwise center-of-load location of the unswept-wing aileron generally remains between the 20- and 50-percent-aileron-chord locations through most of the angle-of-attack range for all control deflections tested. The spanwise center-of-load location is near the midspan of the aileron.

The chordwise center-of-load travel of the swept-wing aileron is somewhat greater than that for the unswept-wing aileron, generally extending from the 20- to 60-percent-chord points for the deflections tested. Again the spanwise center of load remains at about the center of the aileron.

The chordwise center-of-load location on the aileron of the triangular wing also generally lies between the 20- and 60-percent-chord stations and the spanwise location is usually somewhat more inboard than for the other two ailerons, being near the 45-percent-span station of the aileron.

CONCLUDING REMARKS

Some aileron load characteristics for three thin wings varying in sweep have been presented for Mach numbers from 0.80 to 1.05. For the transonic Mach number range, shock effects exert a large influence on the loading, but the exact location of each shock for a specific wing design cannot be catalogued at the present time. It is shown, however, that the aileron loading, although greater in magnitude than at subsonic speeds, nevertheless varies in as uniform a fashion as at subsonic speeds.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 21, 1955.

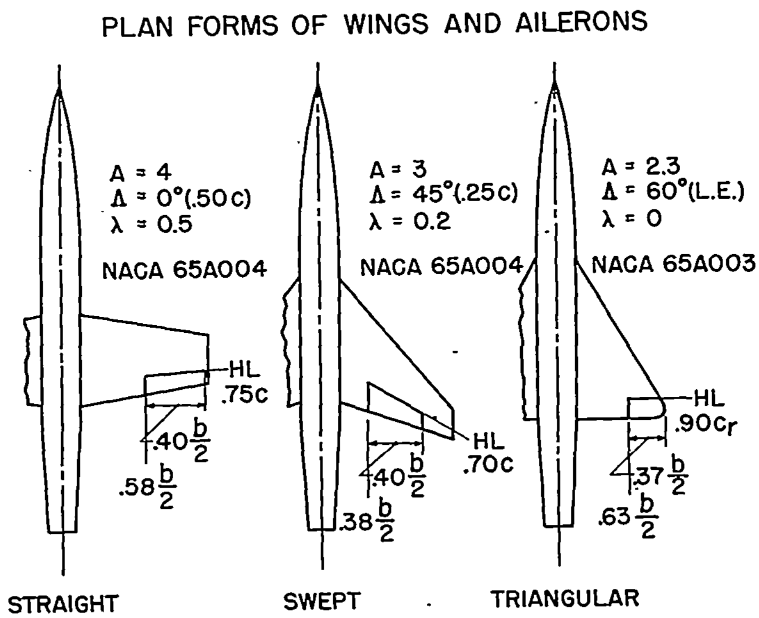

Figure 1

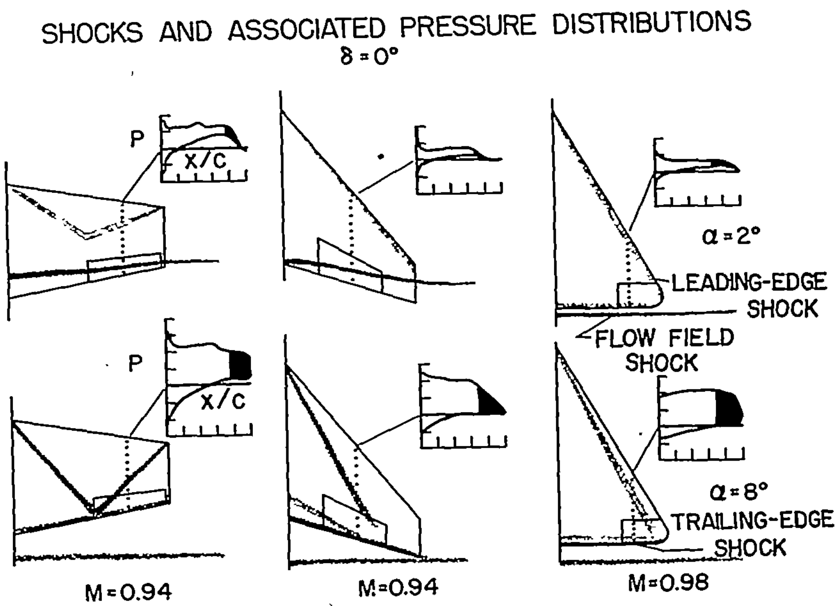

Figure 2

AILERON NORMAL-FORCE COEFFICIENT CHANGE WITH α

UNSWEPT WING

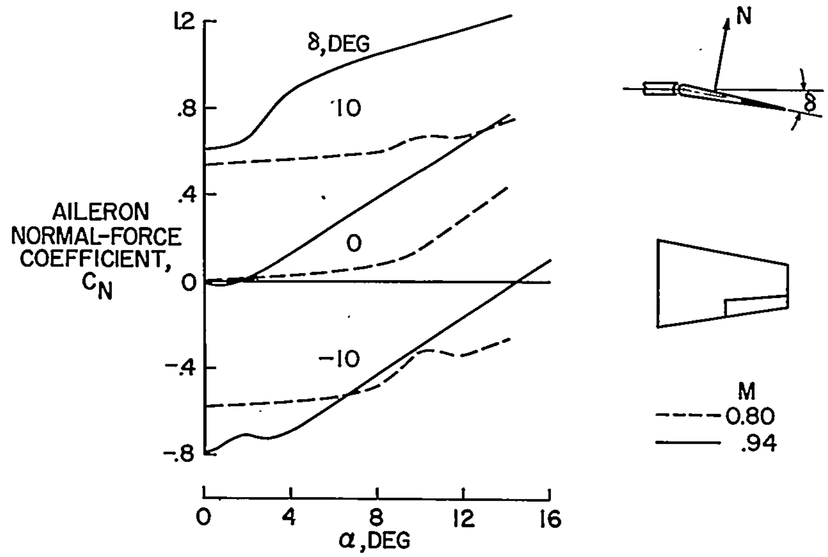

Figure 3

AILERON NORMAL-FORCE COEFFICIENT CHANGE WITH α

SWEPT WING

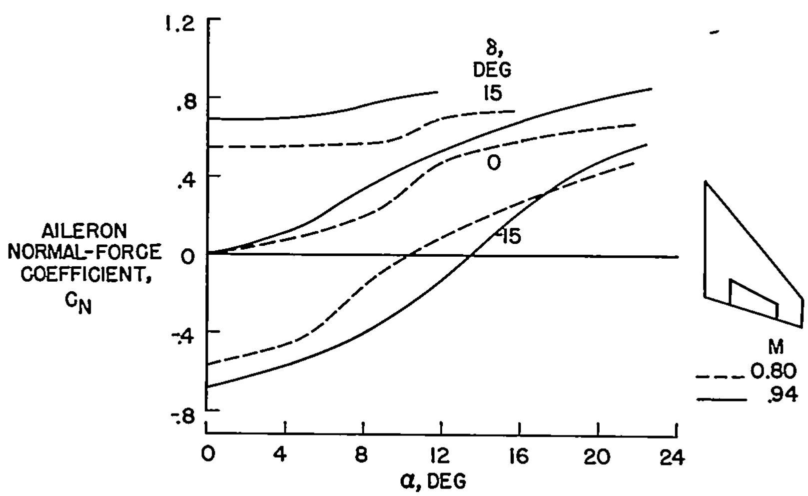

Figure 4

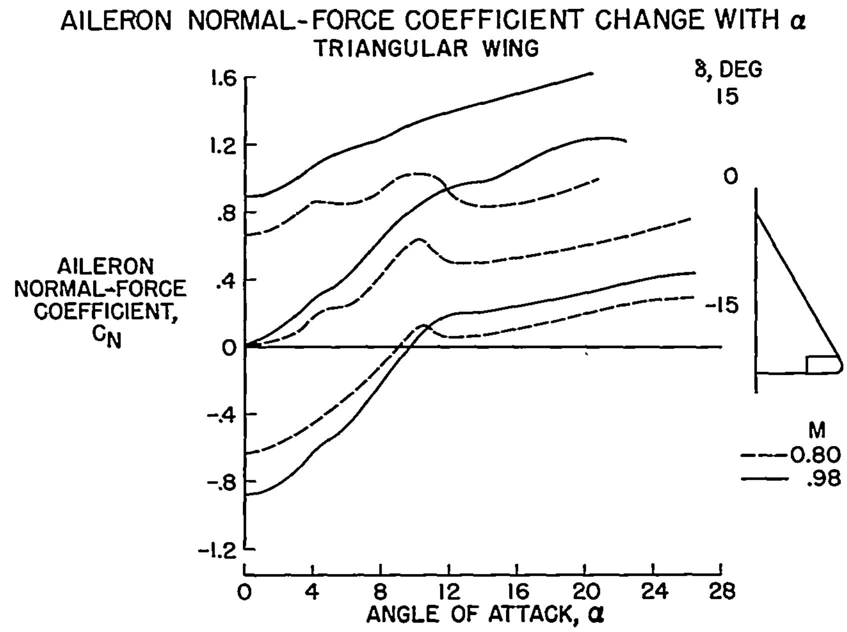

Figure 5

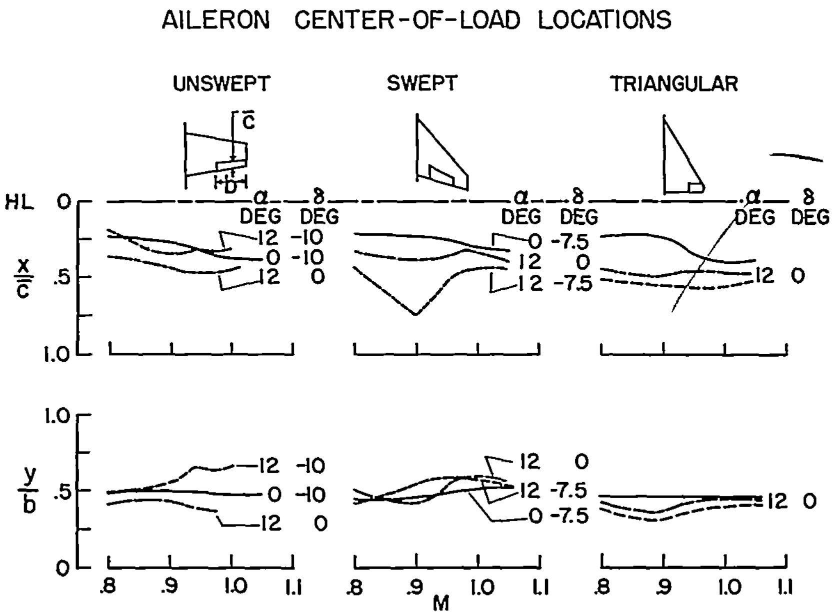

Figure 6